CLAIMS

We claim:

1. A method of partitioning capacity of a network into working capacity and restoration capacity, the method comprising the steps of:

(a) generating a set of network constraints for a network of nodes interconnected by links in accordance with a network topology;

(b) formulating a linear programming problem (LPP) for the network topology based on the set of network constraints; and

(c) generating either an exact or an approximate solution for the LPP, the solution including a working capacity and a restoration capacity of each link of the network.

2. The invention of claim 1, further comprising the step of (d) partitioning the capacity of each link of the network based on the solution for the LPP.

3. The invention of claim 1, wherein, for step (a), the network constraints are 1) for each link, a set of detour paths exist whose capacities sum to the working capacity of the link; 2) for each link, the sum of the working capacity and the restoration capacity shared by the set of detour paths is, at most, a total capacity of the link; and 3) the working capacity of the network is maximized.

4. The invention of claim 1, wherein, for step (b), the LPP formulation is generated for the network having an equal partition size for the working capacity and restoration capacity of each link e of a set E of links in the network, and step (c) generates the solution based on a fraction α for the equal partition size, the fraction α given by:

$$\alpha = \min_{e \in E} \frac{F(e)}{u_e + F(e)}$$

where "min(•)" denotes the mathematical "minimum of •", u_e is the capacity of link e, and $m(e)$ is the maximum flow value between nodes coupled by e when e is removed from the network.

5. The invention of claim 1, wherein, for step (b), the LPP is a path-indexed

LPP formulation.

6. The invention of claim 5, wherein step (c) further comprises the step of (c1) generating a dual of the path-indexed LPP formulation.

7. The invention of claim 6, wherein step (c) further comprises the step of (c2) approximating the solution with a (1+ε) approximation algorithm.

8. The invention of claim 5, wherein, for step (c), the path-indexed LPP formulation is given by:

$$\max \sum_{e:e\in E} \sum_{P:P\in \mathrm{P}_e} f(P), \text{ subject to}$$

$$\sum_{P:P\in \mathrm{P}_e} f(P) + \sum_{P:P\in \mathrm{P}_f, e\in P} f(P) \le u_e \qquad \forall f \ne e, \quad e,f \in E$$

where i and j are indices corresponding to node numbers, "max(•)" denotes the mathematical "maximize •", E denotes a set of links in the network, e and f are links in the network, u_e denotes the capacity of link e, P_e denotes the set of all paths P from node i to node j that do not contain link $(i, j)=e$, and $f(P)$ denotes the restoration traffic on a given path P after failure of the link that it protects.

9. The invention of claim 1, wherein, for step (b), the LPP is a link-indexed LPP formulation.

10. The invention of claim 9, wherein, for step (b), the link-indexed LPP formulation is given by:

$$\max \sum_{(k,l)\in E} x_{kl}$$

$$\sum_{j:(i,j)\in E} y_{ij}^{kl} - \sum_{j:(j,i)\in E} y_{ji}^{kl} = \begin{cases} x_{kl} & if\ i=k \\ -x_{kl} & if\ i=l \\ 0 & otherwise \end{cases}$$

$$\forall\ i \in N,\ (k,l)\in E;\ y_{kl}^{kl} = 0\ \ \forall\ (k,l)\in E$$

$$x_{kl} + y_{kl}^{ij} \le u_{kl}\ \ \forall (i,j),(k,l)\in E,\ (i,j)\ne(k,l)$$

where i, j, k, and l are indices corresponding to node numbers, "max(•)" denotes the mathematical "maximize •", N denotes a set of nodes in the network, E denotes a set of

links in the network, u_{ij} denotes the capacity of link (i,j), x_{ij} $(0 \leq x_{ij} \leq u_{ij})$ denotes a working capacity reserved on link (i, j), y_{ij}^{kl} denotes a network flow equal to x_{ij} from node k to node l using links other than (k, l).

11. The invention of claim 1, wherein, for step (a), the network is either an electro-optical network or a packet-based network.

12. A method of partitioning capacity of links in a network into working capacity and restoration capacity, the method comprising the steps of:

(a) determining a link $\overline{e}$ and a corresponding shortest path P for which a combination of i) a sum of a set of shortest-path link weights of the corresponding path P when $\overline{e}$ fails and ii) a sum of the link weights when each other link not in the corresponding path P fails is a relative minimum;

(b) computing a minimum capacity of i) the capacity of link $\overline{e}$ and ii) the smallest link capacity of each of the links on the corresponding path P;

(c) updating each of the link weights based on the minimum capacity in accordance with a $(1+\varepsilon)$ approximation method;

(d) incrementing, by the minimum capacity, the working capacity on link $\overline{e}$ and the restoration capacity of each link in the given path P; and

(e) repeating steps (a) through (e) until a set of dual feasibility constraints are satisfied.

13. The invention of claim 12, further comprising the step of scaling, if the set of dual feasibility constraints are satisfied, the working capacity and the restoration capacity of each link so as to satisfy a set of primal capacity constraints.

14. The invention of claim 12, wherein the method is implemented by a processor of a centralized network management system.

15. A computer-readable medium having stored thereon a plurality of instructions, the plurality of instructions including instructions which, when executed by a processor, cause the processor to implement a method for partitioning capacity of a network into working capacity and restoration capacity, the method comprising the steps of:

(a) generating a set of network constraints for a network of nodes interconnected by links in accordance with a network topology;

(b) formulating a linear programming problem (LPP) for the network topology based on the set of network constraints; and

(c) generating either an exact or an approximate solution for the LPP, the solution including a working capacity and a restoration capacity of each link of the network.

16. A network having capacity of the network allocated into working capacity and restoration capacity, the network comprising:

means for generating a set of network constraints for the network of nodes interconnected by links in accordance with a network topology;

(b) formulating a linear programming problem (LPP) for the network topology based on the set of network constraints; and

(c) generating either an exact or an approximate solution for the LPP, the solution including a corresponding working capacity and a corresponding restoration capacity of each link of the network.